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Eclipse Mapping of Non-Radial Pulsation in Binary Stars

J. Nuspl

Konkoly Observatory, Budapest, Hungary

I.B. Bíró

Baja Astronomical Observatory, Baja, Hungary

Abstract. We review a slightly modified method of eclipse mapping, applicable to mode identification in eclipsing binaries containing a pulsating component. The observed light curve is used by the procedure without removing from it the badly determined eclipsing part.

1. Introduction

In observing non-radial pulsators one is struggling with the general problem of mode identification. The different methods developed during the last decades for overcoming this obstacle do not lead to an unambiguous answer, and only their combined application gives hope for partial success. Pulsators in binaries, especially those in eclipsing systems, give the possibility to take a more direct approach. During eclipse, the surface of the pulsating component is scanned by the shadow of its companion, and the phase information on its pulsation as well as the associated periodic changes in brightness and surface geometry are convolved into the light curve. The eclipse mapping method can be used to reconstruct this information and the resulting 2D-image then allows the selection of the corresponding harmonics. Statistics show similarity between the spectral distribution of the components in binaries and that of single stars; therefore, results obtained for pulsating members are expected to apply to single pulsators as well. In addition, eclipsing systems have the advantage of having well-defined methods for determining their absolute parameters.

2. Direct predictions and fitting

To model the variations one can decompose the visible surface into triangles, adding their elementary contributions to the total flux or, in the case of velocity fields, adding their weighted profile tag with the Doppler-shifted values (Kallrath & Milone, 1999). In our calculations the following components are taken into account: the variable size of the deformed surface element; the modification of its relative direction; perturbation of temperature stratification; pressure readjustment in surface layers; shifted number ratios of different constituents.

The model calcultions can be classified into three main categories: $\ell + m =$ odd – amplitude increases symmetrically centered on the eclipse; $m \neq 0$ – am-

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plitude increases around the egress and ingress phases, and $m = 0$ – amplitude decreases towards the eclipse centre. The $\ell + m =$ odd case has the interesting property that there is no net variation outside the eclipse due to symmetry, and the increase of the amplitude during the eclipse phase can be interpreted as an increase of noise. Hence, we suggest to re-analyse the observational data that show this feature, which would reveal a couple of such cases.

A direct fit can be conclusive only by selecting between these groups, but the determined (ℓ, m) values within the given class can be altered by slight modification of the added error terms.

3. Eclipse mapping approach

The eclipse mapping method provides a convenient way of solving the inverse problem of the intensity map in a maximally model-independent manner. It determines the smoothest map consistent with the observed data, maximizing an entropic function of the form $S = -\sum I_k \ln(I_k)$ (I_k being the intensities of the image elements) and at the same time imposing constraints on the deviations from observations (usually measured with a χ^2-statistics).

The difference from classical eclipse mappings, as applied to cataclysmic variables (Horne, 1985), is that a *time-dependent* intensity map is to be reconstructed. In our implementation this is handled by decomposing the intensity in two parts, such that from their reconstructions both the amplitude and phase information of the pulsational pattern can be inferred. This works well except for the $m = 0$ case, where an assumed time-dependence must be explicitly included.

Other advantages of the eclipse mapping method over direct fitting are: it uses the original dataset during the optimization, thus avoids the tedious subtraction of an eclipse model from the light curve; several effects are treated together (e.g., the reflection effect and the oscillation); and, most importantly, the discrimination of the modes is possible in a well determined way and over a more extended range of the (ℓ, m) parameter space.

4. Conclusions and future work

Preliminary work suggests good prospects for application of the eclipse mapping method in analyzing the pulsating components of eclipsing binary systems. Datasets with appropriate quality were and are being collected for several objects that will allow testing the method for real cases (Ohshima et al., 2001; Rodríguez et al., 1998). Results of the application of our method for RZ Cas will be published elsewhere.

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